PROC. BIOL. SOC. WASH.
94(4), 1981, pp. 1226–1232

THE PUERULUS AND POST-PUERULUS OF THE HAWAIIAN SPINY LOBSTER *PANULIRUS MARGINATUS*

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Abstract.—Collections of pueruli and post-pueruli at Kure Atoll, Hawaii, provide material for a description of these stages of the Hawaiian endemic spiny lobster, *Panulirus marginatus*. This description allows reliable identification of the two local species of spiny lobsters at the time of settlement. Pueruli of *P. marginatus* are best separated from the other local species, *P. penicillatus* by the shorter forward projection of the supra-orbital spines, the absence of a caudally directed spine on the fifth thoracic sternite, and slightly greater exopod development on the second and third maxillipeds in *P. marginatus*. The diagnostic features of adults have been found to be valid for the post-puerulus stage of both species.

Introduction

The Hawaiian spiny lobster, *Panulirus marginatus* (Quoy and Gaimard, 1825) is restricted to the Hawaiian faunal area (George and Holthuis 1965) including Johnston Atoll (Brock 1973). *Panulirus penicillatus* (Oliver, 1791), a more widely distributed Indo-Pacific spiny lobster (George 1968), is also found in Hawaii. The puerulus stage of *P. penicillatus* was described by Michel (1971). As part of a fishery management investigation by one author (CDM), settling pueruli and post-pueruli were collected on Witham habitats (Witham *et al.* 1968) beginning in May 1979 at Kure Atoll (178°18′W, 28°24′N). The ability to differentiate between these two species at the time of settlement is required to determine the geographic and temporal pattern of larval recruitment of each lobster species, information needed for a sound fisheries management plan. The collection of many *P. marginatus* specimens provided the opportunity to describe the diagnostic features for this previously uncollected stage.

Materials and methods.—These specimens were compared with literature descriptions of known *Panulirus* pueruli and with pueruli of *P. penicillatus* from Hawaii and elsewhere in the Pacific. Specimens that were not *P. penicillatus* were treated initially as presumptive *P. marginatus*. Electrophoretic studies of these specimens (with the exoskeletons retained for morphological examination) revealed in all the presence of the same suite of diagnostic isozymes which separate adult specimens of *P. marginatus* from *P. penicillatus* (J. Shaklee pers. comm.) confirming their identity.

Table 1.—Characters separating pueruli from post-pueruli in *Panulirus*.

Character	Puerulus	Post-puerulus
Body shape	Dorsoventrally flattened	Generally cylindrical
Body spination	6 on dorsal carapace	Many dorsally and laterally on carapace
Exoskeleton	Non-calcified	Calcified
Color	Initially clear, pre-molt pigmented	Brownish green to reddish brown, never clear
Fifth thoracic sternite	With tooth, spine or nub	Evenly rounded
Second pleopod	Endopodite as long as exopodite	Endopodite ½ or less exopodite

Panulirus marginatus material: 30 pueruli collected; 16 May 1979 (#1), 23 June 1979 (#'s 6–18), 1 July 1979 (#'s 26, 27, 29–36), 6 July 1979 (#19–20, 22–25); 6 post-pueruli collected; 26 May 1979 (#'s 2–5), 23 June 1979 (#21), and 28 July 1979 (#28).

Panulirus penicillatus material: 3 pueruli collected Oahu, Hawaii (UH Zool. Dept. ref. coll.), 1 puerulus collected Enewetak Atoll, Marshall Islands, 12 March 1979; 13 post-pueruli collected Enewetak, 12 March 1979.

All material is deposited under Accession No. 810002HA in the collections of the Processing Center, Naval Ocean Systems Center, Hawaii Laboratory, Kailua, Hawaii.

Results.—The characters used to separate pueruli from post-pueruli are listed in Table 1 (also compare Figs. 1a and 2a). The puerulus stage is recognized by its dorsoventral compression, sparse carapace spination, lack of calcification and the presence of well developed pleopods. Color is not particularly useful, as older pueruli approaching the molt become considerably darker. Indeed, at this stage many of the features of the next stage such as carapace spination are visible beneath the cuticle.

The general morphology of *P. marginatus* pueruli conforms to previously published descriptions of *Panulirus* (Bonde 1932; Gordon 1953; Deshmukh 1966; Michel 1971) so only those features which separate it from others in the genus will be described. Like other pueruli these are dorsoventrally compressed with a thin exoskeleton. Early pueruli are transparent (turning white in formalin) except for a distal band and several more proximal transverse reddish brown bands on the antennal flagella. Later pueruli are considerably darker, and on gross examination may be taken for post-pueruli.

The dorsal carapace of *P. marginatus* bears only 6 spines, one pair at the anterior ends of the weak dorsal carinae, one pair behind the orbits, and one pair behind the supra-orbital spines or "horns." These supra-orbital

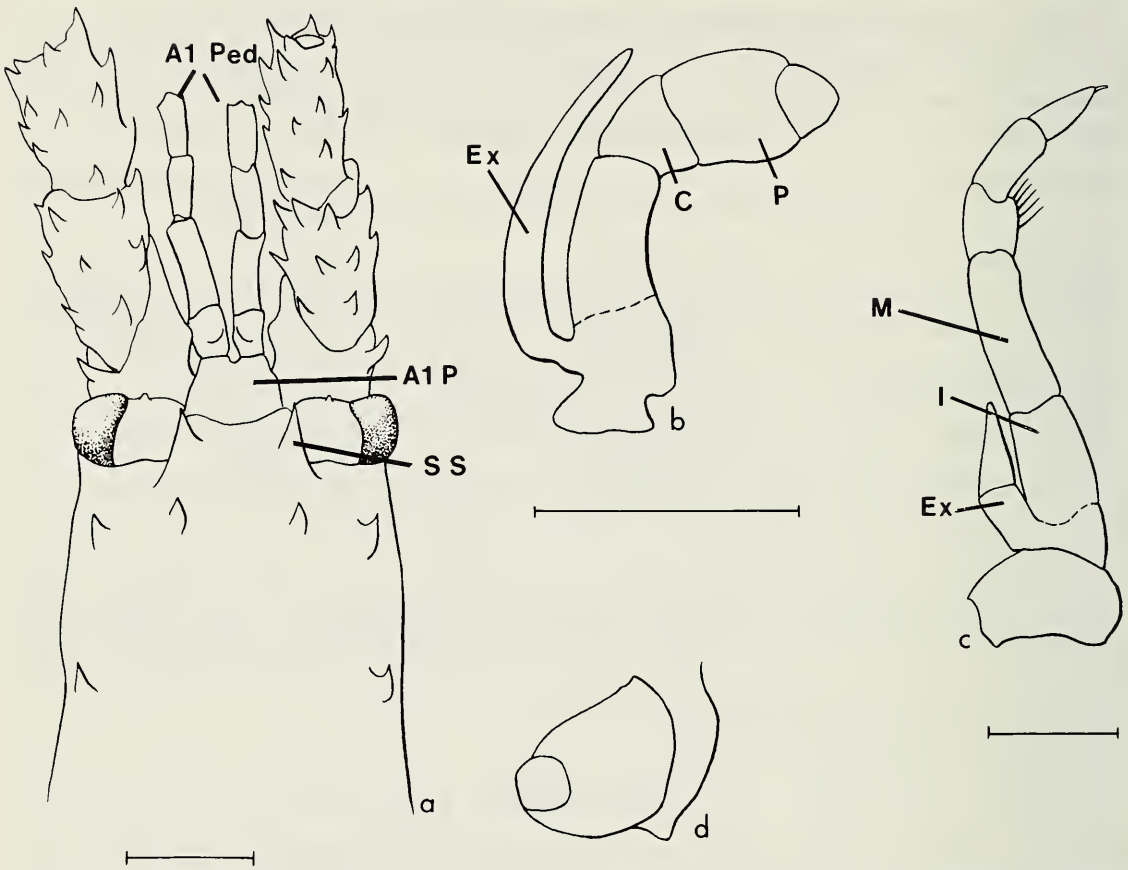

Fig. 1. Puerulus of *P. marginatus:* a, Dorsal view of anterior portion; b, Second maxilliped; c, Third maxilliped; d, Fifth thoracic sternite lateral view. Scale bars: a, 2 mm; b, 1 mm; c and d, 1 mm. Abbr. A1 P, Antennular Plate; A1 Ped, Antennular Peduncle; C, Carpus; Ex, Exopod; I, Ischium; M, Merus; P, Propodus; SS, Supra-orbital Spines.

spines vary in length between 0.3 and 0.7 the distance to the anterior margin of the antennular plate and reach just to the anterior margin of the eyestalks (Fig 1a). In *P. penicillatus* these supra-orbital spines extend past the anterior margin of the eyestalks to or beyond the anterior margin of the antennular plate. The antennular peduncle is relatively long and slender in *P. marginatus* with a width/length ratio of approximately 1:8.4. The antennal flagella tapers distally and is not spatulate. The antennal peduncle is robust and heavily spined with 5–6 spines on the dorsal segment of the second segment.

The exopod of the second maxilliped in *P. marginatus* extends to at least the carpal/propodal articulation and can reach mid-propodus (Fig. 1b). Its greatest length in *P. penicillatus* is mid-carpus. The exopod of the third maxilliped in *P. marginatus* extends well past the ischial/meral articulation with its tip at 0.1 to 0.3 the length of the merus (Fig. 1c). In *P. penicillatus,* the exopod tip is below the ischial/meral articulation.

The fifth thoracic sternite in *P. marginatus* has a ventrally directed non-

Table 2.—Distinguishing characters of *P. marginatus* and *P. penicillatus* at the puerulus stage.

Character	*P. marginatus* (n = 30)	*P. penicillatus* (n = 4)
Supra-orbital spines, apex of	0.3–0.75 length antennular plate	≥ length antennular plate
Antennular peduncle, W/L ratio ($\bar{x}$)	1:8.4	1:6.1
Second maxilliped, apex of	Carpal/propodal articulation to mid-propodus	Mid-carpus
Third maxilliped, apex of	0.1 length merus to 0.3 length merus	0.95 length ischium
Fifth thoracic sternite	Ventrally directed weak nub	Posteriorly directed strong spine

acute nub (Fig. 1d) in lateral view in contrast to *P. penicillatus* which has a posteriorly directed acute spine here. Table 2 summarizes the features which separate the two Hawaiian *Panulirus*. Comparisons with other species are discussed later.

The post-pueruli bear all the distinguishing features of the adults, although usually in a less developed state. In *P. marginatus* this includes the presence of only 2 instead of 4 large spines on the antennular plate (Fig. 2a vis. 2b), and the presence of an uninterrupted dorsal transverse groove on the abdominal somites in contrast to *P. penicillatus* where the groove is medially interrupted. A summary of diagnostic features in the post-puerulus is given in Table 3.

Discussion

Information is available on pueruli of the *P. japonicus* group for *P. japonicus* (Ortmann 1891; Nakazawa 1917; Kinoshita 1934), *P. longipes femoristriga* (Michel 1971), and *P. cygnus* (George 1962). *Panulirus japonicus* is reported to have a vestigial exopod on the third maxilliped (key in Deshmukh 1966) and no spine on the fifth thoracic sternum. Ortmann's (1891) figure 3 shows the supra-orbital spines extending beyond the eyestalks, but not to the anterior margin of the antennular plate; however, Nakazawa's (1917) figure 3 shows the supra-orbital spines extending beyond the eyestalks to the anterior margin of the antennular plate. This figure also shows 5 or 6 spines on the dorsal surface of the second segment of the antennal peduncle. *Panulirus longipes femoristriga* has supra-orbital spines not reaching the anterior margin of the antennular plate, a long slender antennular peduncle with a W/L ratio of 1:8.8, and a more lightly spined (3–4

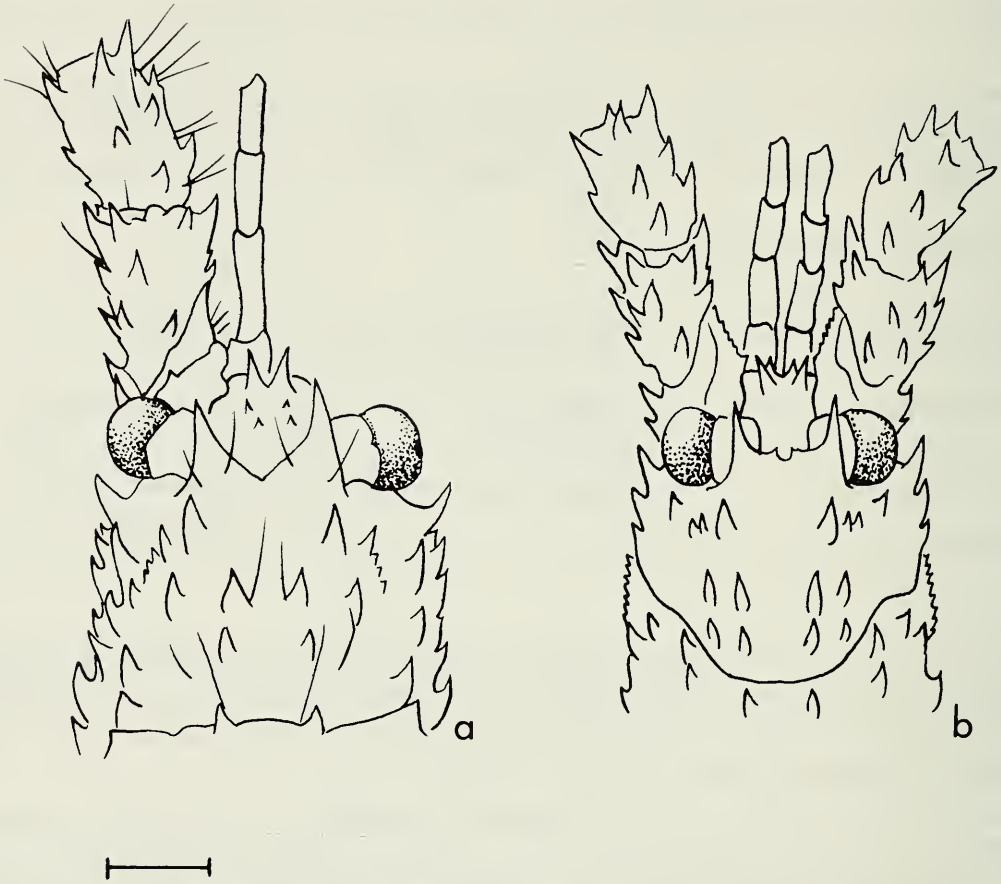

Fig. 2. Post-puerulus of: a, *P. marginatus*; b, *P. penicillatus*. Scale bar: 2 mm.

spines) dorsal surface for the second segment of the antennal peduncle. The exopods of the second and third maxillipeds are well developed, reaching almost to the propodal/dactyl articulation on the second, and well past the ischial/meral articulation on the third. The fifth thoracic sternite has an acute spine directed ventrally. *Panulirus cygnus* has a second maxilliped exopod reaching to the carpal/propodal articulation, a third maxilliped exopod reaching to at least the base of the merus, and no tooth on the posterior margin of the Thoracic sternite. Data on the other features were not given by George (1962).

Panulirus japonicus group adults are characterized by flagellate exopods on the second and third maxillipeds, an antennular plate with only two large spines, and uninterrupted dorsal transverse grooves on the five abdominal somites according to George and Holthuis (1965). *Panulirus penicillatus* is considered by them to be the most closely related Indo-Pacific species outside the group. Since *P. marginatus, P. longipes femoristriga, P. cygnus,* and the related *P. penicillatus* all have well developed third maxilliped exopods, the "vestigial" exopod of *P. japonicus* is difficult to explain, and should be confirmed by reexamination. If indeed it is vestigial

Table 3.—Distinguishing characters of *P. marginatus* and *P. penicillatus* at the post-puerulus stage.

Character	*P. marginatus* (n = 6)	*P. penicillatus* (n = 13)
Supra-orbital spines, apex of	0.5–1.0 length antennular plate	≥ length antennular plate
Supra-orbital spines, medial region	Smoothly concave	Notched, with small teeth laterally
Antennular plate, number of spines	2 (plus spinules)	4 (plus spinules)
Antennular peduncle, W/L ratio ($\bar{x}$)	1:10.6	1:8.2
Antennal peduncle, W/L 2nd seg. ($\bar{x}$)	1:1.85	1:1.48
Second maxilliped, apex of	Mid-propodus	Mid-carpus to carpal/ propodal articulation
Third maxilliped, apex of	0.1 length merus to 0.3 length	0.2 length ischium to 0.6 length
Abdominal somites	Dorsal transverse groove uninterrupted	Groove interrupted medially

as described, it would provide a link from the *P. japonicus* group to other *Panulirus* species which have vestigial exopods in the puerulus stage, and indistinct non-flagellate exopods in the adult stage.

Differentiation of pueruli of the two local species is decisive. However, some confusion may be encountered in separating *P. marginatus* pueruli from others in the *P. japonicus* group. If *P. japonicus* really has a vestigial third maxilliped exopod this would be the clearest separation; otherwise, the greater relative length of the supra-orbital spines in *P. japonicus* might separate the two. *Panulirus longipes femoristriga* can be separated by its less spinose antennal peduncle and the acute tooth on the fifth thoracic sternite. For *P. cygnus,* the only good features for separation are apparently the slightly greater development of the maxilliped exopods in *P. marginatus*. In the *P. japonicus* group, only the puerulus of *P. pascuensis* has not been described. Clearly, the known pueruli of this species group show a homogeneity of most features, which in our opinion, validates George and Holthuis's (1965) recognition of these species as more closely related to each other than to other *Panulirus* species.

Acknowledgments

This paper is a portion of "Population Biology of Spiny Lobsters throughout the Hawaiian Archipelago," a research project sponsored by the Uni-

versity of Hawaii Sea Grant College Program under Institutional Grant Nos. 04-8-MOI-178 and NA79AA-D-00085 from NOAA, Office of Sea Grant, U.S. Department of Commerce, and by State of Hawaii through the Office of the Marine Affairs Coordinator; this paper is University of Hawaii Sea Grant College Program Journal Contribution No. UNIHI-SEAGRANT-JC-82-001. We thank S. Grenier, S. Kyed, Jr., and T. Malott for assistance in collecting at Kure Atoll, and M. DeGruy for collecting at Enewetak Atoll. We are grateful to S. Monden for preparing the illustrations. The United States Coast Guard 14th District provided logistical support at Kure for which we are deeply indebted.

Literature Cited

Bonde, W. von. 1932. Post-brephalus development of some South African Macrura.—Report Fisheries Marine Biology Survey South Africa 8, Special Report 1:1–42.

Brock, R. E. 1973. A new distributional record for *Panulirus marginatus* (Quoy and Gaimard, 1825).—Crustaceana 25:111–112.

Deshmukh, S. 1966. The puerulus of the spiny lobster *Panulirus polyphagus* (Herbst) and its metamorphosis into the post-puerulus.—Crustaceana 10:137–150.

George, R. W. 1962. Description of *Panulirus cygnus* sp. nov. the commercial crayfish (or spiny lobster) of Western Australia.—Journal Royal Society Western Australia 45:100–110.

———. 1968. Tropical spiny lobsters, *Panulirus* spp. of Western Australia (and the Indo-West Pacific).—Journal Royal Society Western Australia 51:33–38.

———, and L. B. Holthuis. 1965. A revision of the Indo-West Pacific spiny lobsters of the *Panulirus japonicus* group.—Zoologische Verhandelingen 72:1–36.

Gordon, I. 1953. On the puerulus stage of some spiny lobsters.—Bulletin British Museum (NH) 2:17–42.

Kinoshita, T. 1934. Studies on puerulus of spiny lobster, *Panulirus japonicus* (v. Seibold), and its later metamorphosis.—Dobutssu Zasshi (Tokyo) 46:391–399. (in Japanese)

Michel, A. 1971. Note sur les puerulus de Panuliridae et les larves phyllosomes de *Panulirus homarus* (L).—Cahiers ORSTOM, serie Oceanographie, 9:459–473.

Nakazawa, K. 1917. On the metamorphosis of *Panulirus japonicus*.—Dobutssu Zasshi (Tokyo) 29:259–267. (in Japanese)

Ortmann, A. 1891. Die Decopoden-Krebse des Strassburger Museums. III. Die Abtheilungen der Reptantia Boas: Homaridea, Loricata, und Thalassinidea.—Zoologishe Jahrbucher (Syst.) 6:1–58.

Witham, R., R. M. Ingle, and E. A. Joyce. 1968. Physiological and ecological studies of *Panulirus argus* from the St. Lucie estuary.—Florida State Board of Conservation Technical Series 53:1–31.

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